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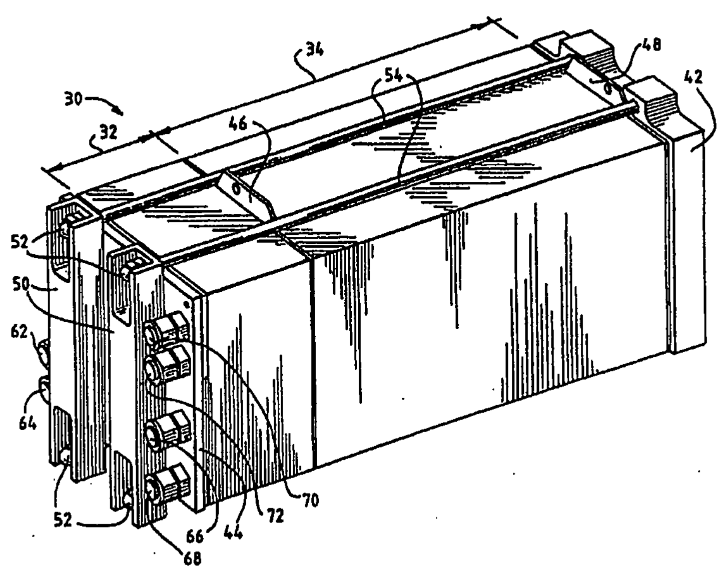

(57) Abstract

An electrochemical fuel cell stack (30) has a compact, compression assembly which includes a plurality of non-intersecting compression bars (50). Each of the compression bars (50) extends across a central portion of the adjacent first end plate (44). The central portion corresponds to the central, catalytically active region of the anode layer and the cathode layer of the fuel cells which make up the stack. The compressive assembly also includes compressive means for fastening each of the compression bars to a second end assembly (42) at the opposite end of the stack. The compressive fastening means urges the compression bars against the first end plate so as to urge the first end plate toward the second end assembly, thereby applying compressive force to the fuel cells to promote sealing and electrical contact between the layers forming the fuel cell stack.

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ELECTROCHEMICAL FUEL CELL STACK WITH COMPACT, CENTRALLY DISPOSED COMPRESSION MECHANISM

Field Of The Invention

The present invention relates to electrochemical fuel cells. More particularly, the present invention relates to an electrochemical fuel cell stack in which the mechanism for securing the stack in its compressed, assembled state includes compact, centrally disposed compression members, rather than peripherally disposed tie rods as in conventional stack designs.

Background Of The Invention

Electrochemical fuel cells convert fuel and oxidant to electricity and reaction product. Solid polymer electrochemical fuel cells generally employ a membrane electrode assembly ("MEA") consisting of a solid polymer electrolyte or ion exchange membrane disposed between two electrodes formed of porous, electrically conductive sheet material, typically carbon fiber paper. The MEA contains a layer of catalyst, typically in the form of finely comminuted platinum, at each membrane/electrode interface to induce the desired electrochemical reaction. The electrodes are electrically coupled to provide a path for conducting electrons between the electrodes to an external load.

At the anode, the fuel permeates the porous electrode material and reacts at the catalyst layer to form cations, which migrate through the membrane to the cathode. At the cathode, the oxygen-

containing gas supply reacts at the catalyst layer to form anions. The anions formed at the cathode react with the cations to form a reaction product.

In electrochemical fuel cells employing hydrogen as the fuel and oxygen-containing air (or substantially pure oxygen) as the oxidant, the catalyzed reaction at the anode produces hydrogen cations (protons) from the fuel supply. The ion exchange membrane facilitates the migration of hydrogen ions from the anode to the cathode. In addition to conducting hydrogen ions, the membrane isolates the hydrogen-containing fuel stream from the oxygen-containing oxidant stream. At the cathode, oxygen reacts at the catalyst layer to form anions. The anions formed at the cathode react with the hydrogen ions that have crossed the membrane to form liquid water as the reaction product. The anode and cathode reactions in hydrogen/oxygen fuel cells are shown in the following equations:

Anode reaction: $H_2 \rightarrow 2H^+ + 2e^-$

Cathode reaction: $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$

In typical fuel cells, the MEA is disposed between two electrically conductive plates, each of which has at least one flow passage engraved or milled therein. These fluid flow field plates are typically formed of graphite. The flow passages direct the fuel and oxidant to the respective electrodes, namely, the anode on the fuel side and the cathode on the oxidant side. In a single cell arrangement, fluid flow field plates are provided

on each of the anode and cathode sides. The plates act as current collectors, provide support for the electrodes, provide access channels for the fuel and oxidant to the respective anode and cathode surfaces, and provide channels for the removal of water formed during operation of the cell.

Two or more fuel cells can be connected together, generally in series but sometimes in parallel, to increase the overall power output of the assembly. In series arrangements, one side of a given plate serves as an anode plate for one cell and the other side of the plate can serve as the cathode plate for the adjacent cell. Such a series connected multiple fuel cell arrangement is referred to as a fuel cell stack, and is usually held together in its assembled state by tie rods and end plates. The stack typically includes manifolds and inlet ports for directing the fuel (substantially pure hydrogen, methanol reformate or natural gas reformate) and the oxidant (substantially pure oxygen or oxygen-containing air) to the anode and cathode flow field channels. The stack also usually includes a manifold and inlet port for directing the coolant fluid, typically water, to interior channels within the stack to absorb heat generated by the exothermic reaction of hydrogen and oxygen within the fuel cells. The stack also generally includes exhaust manifolds and outlet ports for expelling the unreacted fuel and oxidant gases, each carrying entrained water, as well as an exhaust manifold and outlet port for the coolant water exiting the stack. It is generally convenient to locate all of the inlet and outlet ports at the same end of the

stack.

In conventional fuel cell designs, such as, for example, the fuel cells described and illustrated in U.S. Patent Nos. 3,134,697, 3,297,484, 3,297,490, 4,057,479, 4214,969 and 4,478,917, the plates which make up each conventional fuel cell assembly are compressed and maintained in their assembled states by tie rods. The tie rods extend through holes formed in the peripheral edge portion of the plates and have associated nuts or other fastening means assembling the tie rods to the fuel cell assembly and compressing the end plates of the fuel cell assembly toward each other. The reason for employing a peripheral edge location for the tie rods in conventional designs is to avoid the introduction of openings or otherwise interfering with the central, electrochemically active portion of the fuel cell.

The peripheral edge location of the tie rods in conventional fuel cell designs has inherent disadvantages. First, the peripheral location of the tie rods requires that the thickness of the end plates be substantial in order to transmit the compressive force across the entire area of the plate. End plates having insufficient thickness to transmit such compressive force will not adequately compress the center region of the end plates and the various interior humidification and active section plates interposed between the end plates. Inadequate compressive forces can compromise the seals associated with the manifolds and flow fields in the central regions of the interior plates, and also compromise the electrical contact required

along the surfaces of the plates to provide the serial electrical connection among the fuel cells which make up the stack. However, end plates of substantial thickness contribute significantly to the overall weight and volume of the fuel cell stack, both of which are preferable to minimize, particularly in motive fuel cell applications.

Additionally, the peripheral location of the tie rods induces deflection of the end plates over time, thereby distorting the end plates so as to render them convex, the distance between the peripheral edges of the end plates being less than the distance between the centers of the end plates. Such distortion produces a nonuniform and unpredictable distribution of compressive forces across the area of the end plates, thereby further compromising the seals associated with the manifolds and flow fields in the central regions of the interior plates which make up the stack, as well as the electrical contact required between the serially arranged fuel cell plates.

A structure for incorporating a fuel cell, which includes centrally disposed compression bars, is described and illustrated as prior art in U.S. Patent No. 4,997,728, specifically Fig. 2. That prior art design also has inherent disadvantages, namely, the two sets of compression pads 14 between the end ("pressing") plate 10 and the upper bars 13 have different thicknesses because of the differing elevations of the upper bars from the end plate. Such variances in thicknesses are disadvantageous in terms of ease of assembling the fuel cell structure and the need to maintain an inventory of at least two distinct thicknesses of compression

pads. Moreover, the crossed configuration of the upper bars 13 in the '728 patent necessarily renders the elevation of one of the upper bars from the end plate greater than the elevation of the other upper bar, thereby increasing the overall length (and volume) of the fuel cell assembly.

Accordingly, it is an object of the present invention to provide a compact compression mechanism for a fuel cell stack that distributes force substantially uniformly across the area of the adjacent end plate.

It is also an object of the invention to provide a compact compression mechanism for a fuel cell stack that is centrally disposed with respect to the adjacent end plate so as to avoid distortion of the end plate produced by conventional, peripherally disposed compression mechanisms.

Summary Of The Invention

The above and other objects are achieved by an electrochemical fuel cell stack comprising:

a. a first end plate;

b. a second end assembly;

c. at least one electrochemical fuel cell interposed between the first end plate and the second end assembly, the at least one fuel cell comprising an anode layer, a cathode layer and an electrolyte interposed between the anode layer and the cathode layer, each of the anode layer and cathode layer having a central, catalytically active region;

d. a compression assembly comprising:

1. a plurality of non-intersecting

compression bars, each of the plurality of compression bars extending across a central portion of the first end plate, the central portion corresponding to the central, catalytically active region of the anode and the cathode; and

2. compressive means for fastening each of the plurality of compression bars to the second end assembly.

In operation, the compressive fastening means urges the plurality of compression bars against the first end plate so as to correspondingly urge the first end plate toward the second end assembly, thereby applying compressive force to the at least one fuel cell.

In the preferred electrochemical fuel cell stack, the compressive fastening means comprises a tie rod having first and second ends. The first end extends through an opening formed in one of the plurality of compression bars and the second end extends through an opening in the second end assembly. A first fastener retains the first end against the compression bar and a second fastener retains the second end against the second end assembly.

In the preferred electrochemical fuel cell stack, each of the plurality of compression bars has a cavity formed on the side facing the first end plate. The compression assembly further comprises compressive means mounted within the cavity for urging each of the plurality of compression bars away from the first end plate.

The compressive urging means preferably comprises at least one disc-spring washer. The compressive urging means most preferably comprises a plurality of stacked disc-spring washers. The compressive urging means can also comprise a coiled spring.

In the preferred electrochemical fuel cell stack, each of the plurality of compression bars has a longitudinal axis and the longitudinal axis of each of the plurality of compression bars is oriented in parallel with the longitudinal axes of the remainder of the plurality of compression bars.

In the preferred electrochemical fuel cell stack, the plurality of compression bars consists of a pair of compression bars.

In an embodiment of the electrochemical fuel cell stack with a compact, centrally disposed compression mechanism at each end of the stack, the plurality of compression bars is a plurality of first compression bars, the second end assembly preferably comprises a second end plate and a plurality of non-intersecting second compression bars. Each of the plurality of second compression bars extends across a central region of the second end plate. The central region corresponds to the central, catalytically active region of the anode layer and the cathode layer. The compressive fastening means preferably comprises a tie rod having first and second ends. The first end extends through an opening formed in one of the plurality of first compression bars and the second end extends through an opening in one of the plurality of second compression bars. A first fastener retains the first end against the first compression bar and a second fastener retains the

second end against the second compression bar.

Brief Description Of The Drawings

FIG. 1 is a perspective view of a preferred embodiment of an electrochemical fuel cell stack with a compact, centrally disposed compression mechanism.

FIG. 2 is an front end elevation view of the electrochemical fuel cell stack illustrated in FIG. 1.

FIG. 3 is a sectional view of the electrochemical fuel cell stack taken in the direction of arrows A-A in FIG. 2.

FIG. 4 is a rear end elevation view of the electrochemical fuel cell stack illustrated in FIGS. 1-3, showing the end opposite that illustrated in FIG. 2.

FIG. 5 is a partial top view, partially in section of the electrochemical fuel cell stack illustrated in FIGS. 2-4.

FIG. 6 is a bottom view of the compression bar employed in the electrochemical fuel cell stack illustrated in FIGS. 1-5, showing the side of the compression bar facing the adjacent end plate.

FIG. 7 is a side sectional view of the compression bar illustrated in FIG. 7.

FIG. 8 is a perspective view of another embodiment of an electrochemical fuel cell stack with a compact, centrally disposed compression mechanism at each end of the stack.

FIG. 9 is a rear end elevation view of the electrochemical fuel cell stack illustrated in FIG. 8, showing the end corresponding to that illustrated in FIG. 4.

Detailed Description Of The Preferred Embodiments

Turning first to FIG. 1, an electrochemical fuel cell stack 30 has a humidification section 32 located upstream from the electrochemically active section 34. Stack 30 is a modular plate and frame design, and includes a compression end plate 42 and a fluid end plate 44. Compression end plate 42 has a pneumatic bladder (not shown) mounted on its surface facing active section 34, which compresses the plates which make up fuel cell stack 30, thereby promoting sealing and electrical contact between the plates of the stack. Bus plates 46 and 48, which are located on opposite ends of active section 34, provide the negative and positive contacts, respectively, to draw current generated by the assembly to a load (not shown in FIG. 1). Tie rods 54 extend between fluid end plate 44 and compression bars 50 to retain and secure stack 30 in its assembled state with fastening nuts 52.

As shown in FIG. 1, fluid end plate 44 has extending therefrom the six inlet and outlet ports for connecting the incoming and outgoing reactant and coolant streams to the stack. The ports are inlet fuel stream port 62, outlet fuel stream port 64, inlet oxidant stream port 66, outlet oxidant stream port 68, inlet coolant stream port 70, and outlet coolant stream port 72.

FIG. 2 is a front end elevation view of the electrochemical fuel cell stack illustrated in FIG. 1. FIG. 2 shows fluid end plate 44 and compression bars 50 retaining and securing stack 30 in its assembled state with fastening nuts 52. Inlet fuel stream port 62, outlet fuel stream port 64, inlet oxidant stream port 66, outlet oxidant stream port

68, inlet coolant stream port 70, and outlet coolant stream port 72 extend from fluid end plate 44. Ports 74 and support channel member 76 are described in more detail below in connection with FIGS. 3 and 4.

FIG. 3 is a sectional view of the stack 30 taken in the direction of arrows A-A in FIG. 2. As shown in FIG. 3, active section 34 includes, in addition to bus plates 46 and 48, a plurality of recurring fuel cell units. Each cell consists of a membrane electrode assembly 96 interposed between two reactant flow field plates 94. A coolant flow field plate 98 is inserted at regular intervals to provide a cooling cell or jacket 98 for removing heat generated by the electrochemical reaction occurring in the cells of the active section 34. The cells of the active section 34 are electrically coupled in series by virtue of the contact between the electrically conductive sheets that form the layers of the cells.

As shown in FIG. 3, humidification section 32 includes a plurality of humidification cells, one of which is designated in FIG. 3 as humidification cell 92. Each humidification cell 92 consists of a reactant fluid flow field plate (not shown in FIG. 3), a water flow field plate (not shown), and a water vapor transport membrane (not shown) interposed between the reactant fluid flow field plate and the water flow field plate. In humidification section 32, water vapor is imparted to the fuel and oxidant streams prior to introducing the reactant streams to active section 34.

Further components of the compression bars 50

and the compression end plate 42 are also shown in FIG. 3. Each compression bar 50 has a plurality of disc-spring washers 80 stacked in a cavity formed in its underside to urge the compression bar 50 away from the remainder of stack 30, thereby compressing the layers to promote sealing of the stack. Compression end plate 42 has a pneumatic piston 84 positioned within it to apply uniform pressure to the assembly, thereby promoting sealing. Support channel member 76, the ends of which are also shown in FIGS. 2 and 4, extends the length of humidification section 32 and active section 34 in order to preserve the alignment and prevent the sagging of the plates which make up stack 30.

FIG. 4 is a rear end elevation view of stack 30 illustrated in FIG. 1, showing the end opposite that illustrated in FIG. 2. Compression end plate 42 is retained and secured to the remainder of stack 30 by bolt heads 82 located at the end of tie rods 54 opposite fastening nuts 52 (not shown in FIG. 4). Ports 74, also shown in FIG. 2, allow the introduction of pressurized fluid to the bladder between pneumatic piston 84 and compression end plate 42 (see FIG. 3), thereby promoting sealing and electrical contact between the plates which make up stack 30.

FIG. 5 is a partial top view, partially in section, of stack 30 illustrated in FIGS. 1-4. A portion of the humidification section, which includes humidification cell 92, is illustrated in FIG. 5. FIG. 5 also shows compression bars 50 secured to stack 30 by nuts 52 at the end of tie rods 54.

FIG. 6 is a bottom view of the compression bar employed in the electrochemical fuel cell stack illustrated in FIGS. 1-5. In particular, FIG. 6 shows the side of the compression bar 50 which faces the adjacent end plate (not shown in FIG. 6 but shown, for example, as end plate 44 in FIGS. 2, 3 and 5). As shown in FIG. 6, compression bar 50 preferably includes a pair of oppositely disposed recessed portions 352a and 352b, into which a first pair of holes 354a and 354b is formed to accommodate the insertion of tie rods, such as the one shown as tie rod 54 in FIG. 3, through the holes 354a and 354b. Similarly, a second pair of holes 356a and 356b is formed in the recessed portions 352a and 352b of compression bar 50. Holes 356a and 356b accommodate the insertion of fasteners (not shown in FIG. 6) to attach compression bar 50 to the adjacent end plate.

As shown in FIG. 6, compression bar 50 also has a pair of cylindrical cavities or bores 362a and 362b formed therein. Each of the cavities 362a and 362b can accommodate a plurality of disc-spring washers (not shown in FIG. 6 but shown in FIG. 3 as disc-spring washers 80). As discussed above with respect to FIG. 3, the disc-spring washers urge the compression bar 50 away from the adjacent end plate, thereby compressing the plates to promote sealing and electrical contact. A recess 358 is also formed in compression bar 50 to reduce its weight.

FIG. 7 is a side sectional view of the compression bar 50 illustrated in FIG. 6, showing recesses 352a and 352b, first pair of holes 354a and 354b, second pair of holes 356a and 356b,

cavities 362a and 362b, and weight-reducing recess 358.

FIG. 8 shows another embodiment of the fuel cell stack in which a compact, centrally disposed compression mechanism is configured at each end of the stack 430. The humidification section 432 and active section 434 are substantially identical to humidification section 32 and active section 34 of stack 30 shown in FIGS. 1-3 and 5. Stack 430 includes a compression end plate 442 and a fluid end plate 444. Compression end plate 442 is significantly thinner than compression end plate 42 of stack 30 shown in FIGS. 1-3 and 5, because plate 442 does not include a pneumatic bladder on the surface of plate 442 facing the active section. Bus plates 446 and 448, located on opposite ends of active section 434, are substantially identical to bus plates 446 and 448 in FIG. 1, and provide the negative and positive contacts, respectively, to draw current generated by the assembly to a load (not shown in FIG. 8). As further shown in FIG. 8, tie rods 454 extend between corresponding ones of compression bars 450 and compression bars 480 to retain and secure stack 430 in its assembled state with fastening nuts 452. Each of the compression bars 480 are substantially identical to each of the compression bars 450, which are in turn substantially identical to each of the compression bars 50 shown in FIGS. 1-3 and 5. Specifically, each compression bar 458 has a plurality of disc-spring washers (not shown) stacked in a cavity formed in its underside to urge each compression bar 480 away from plate 442, thereby compressing the layers to promote sealing of stack 430.

As shown in FIG. 8, fluid end plate 444 has extending therefrom the six inlet and outlet ports for connecting the incoming and outgoing reactant and coolant streams to stack 430. The ports are inlet fuel stream port 462, outlet fuel stream port 464, inlet oxidant stream port 466, outlet oxidant stream port 468, inlet coolant stream port 470, and outlet coolant stream port 472.

FIG. 9 is a rear end elevation view of stack 430 illustrated in FIG. 8, showing the end corresponding to the end of stack 30 illustrated in FIG. 4. Compression bars 480 are retained and secured to plate 442 by bolt heads 482 located at the end of tie rods 454 opposite fastening nuts 452 (not shown in FIG. 9). The urging together of compression bars 450 and 480 by the tie rods 454, bolt heads 482 and fastening nuts 452 promotes sealing and electrical contact between the plates which make up stack 430. Support channel member 476, the end of which is shown in FIG. 9, extends the length of humidification section 432 and active section 434 in order to preserve the alignment and prevent the sagging of the plates which make up stack 430.

While particular elements, embodiments and applications of the present invention have been shown and described, it will be understood, of course, that the invention is not limited thereto since modifications may be made by those skilled in the art, particularly in light of the foregoing teachings. It is therefore contemplated by the appended claims to cover such modifications as incorporate those features which come within the spirit and scope of the invention.

What is claimed is:

1. In an electrochemical fuel cell stack comprising a first end plate, a second end assembly and at least one electrochemical fuel cell interposed between said first end plate and said second end assembly, said at least one fuel cell comprising an anode layer, a cathode layer and an electrolyte interposed between said anode layer and said cathode layer, each of said anode layer and cathode layer having a central, catalytically active region, the improvement comprising a compression assembly comprising:

a. a plurality of non-intersecting compression bars, each of said plurality of compression bars extending across a central portion of said first end plate, said central portion corresponding to the central, catalytically active region of said anode layer and said cathode layer; and

b. compressive means for fastening each of said plurality of compression bars to said second end assembly;

whereby said compressive fastening means urges said plurality of compression bars against said first end plate so as to correspondingly urge said first end plate toward said second end assembly, thereby applying compressive force to said at least one fuel cell.

2. The electrochemical fuel cell stack of claim 1 wherein said electrolyte is an ion exchange membrane.

3. The electrochemical fuel cell stack of claim 1 wherein said compressive fastening means comprises a tie rod having first and second ends, said first end extending through an opening formed in one of said plurality of compression bars and said second end extending through an opening in said second end assembly, a first fastener for retaining said first end against said compression bar and a second fastener for retaining said second end against said second end assembly.

4. The electrochemical fuel cell stack of claim 1 wherein each of said plurality of compression bars has a cavity formed on the side facing said first end plate, said compression assembly further comprising compressive means mounted within said cavity for urging each of said plurality of compression bars away from said first end plate.

5. The electrochemical fuel cell stack of claim 4 wherein said compressive urging means comprises at least one disc-spring washer.

6. The electrochemical fuel cell stack of claim 5 wherein said compressive urging means comprises a plurality of stacked disc-spring washers.

7. The electrochemical fuel cell stack of claim 4 wherein said compressive urging means comprises a coiled spring.

8. The electrochemical fuel cell stack of

claim 1 wherein each of said plurality of compression bars has a longitudinal axis and the longitudinal axis of each of said plurality of compression bars is oriented in parallel with the longitudinal axes of the remainder of said plurality of compression bars.

9. The electrochemical fuel cell stack of claim 1 wherein said plurality of compression bars consists of a pair of compression bars.

10. The electrochemical fuel cell stack of claim 1 wherein said plurality of compression bars is a plurality of first compression bars, and wherein said second end assembly comprises a second end plate and a plurality of non-intersecting second compression bars, each of said plurality of second compression bars extending across a central region of said second end plate, said central region corresponding to the central, catalytically active region of said anode layer and said cathode layer, and wherein said compressive fastening means comprises a tie rod having first and second ends, said first end extending through an opening formed in one of said plurality of first compression bars and said second end extending through an opening in one of said plurality of second compression bars, a first fastener for retaining said first end against said one of said plurality of first compression bars and a second fastener for retaining said second end against said one of said plurality of second compression bars.

11. The electrochemical fuel cell stack of claim 10 wherein each of said plurality of first and second compression bars consists of a pair of compression bars.

12. An electrochemical fuel cell stack comprising:

a. a first end plate;

b. a second end assembly;

c. at least one electrochemical fuel cell interposed between said first end plate and said second end assembly, said at least one fuel cell comprising an anode layer, a cathode layer and an electrolyte interposed between said anode layer and said cathode layer, each of said anode layer and cathode layer having a central, catalytically active region;

d. a compression assembly comprising:

1. a plurality of non-intersecting compression bars, each of said plurality of compression bars extending across a central portion of said first end plate, said central portion corresponding to the central, catalytically active region of said anode and said cathode; and

2. compressive means for fastening each of said plurality of compression bars to said second end assembly;

whereby said compressive fastening means urges said plurality of compression bars against said first end plate so as to correspondingly urge said first end plate toward said second

end assembly, thereby applying compressive force to said at least one fuel cell.

13. The electrochemical fuel cell stack of claim 12 wherein said electrolyte is an ion exchange membrane.

14. The electrochemical fuel cell stack of claim 12 wherein said compressive fastening means comprises a tie rod having first and second ends, said first end extending through an opening formed in one of said plurality of compression bars and said second end extending through an opening in said second end assembly, a first fastener for retaining said first end against said compression bar and a second fastener for retaining said second end against said second end assembly.

15. The electrochemical fuel cell stack of claim 12 wherein each of said plurality of compression bars has a cavity formed on the side facing said first end plate, said compression assembly further comprising compressive means mounted within said cavity for urging each of said plurality of compression bars away from said first end plate.

16. The electrochemical fuel cell stack of claim 15 wherein said compressive urging means comprises at least one disc-spring washer.

17. The electrochemical fuel cell stack of claim 16 wherein said compressive urging means comprises a plurality of stacked disc-spring

washers.

18. The electrochemical fuel cell stack of claim 15 wherein said compressive urging means comprises a coiled spring.

19. The electrochemical fuel cell stack of claim 12 wherein each of said plurality of compression bars has a longitudinal axis and the longitudinal axis of each of said plurality of compression bars is oriented in parallel with the longitudinal axes of the remainder of said plurality of compression bars.

20. The electrochemical fuel cell stack of claim 12 wherein said plurality of compression bars consists of a pair of compression bars.

21. The electrochemical fuel cell stack of claim 12 wherein said plurality of compression bars is a plurality of first compression bars, and wherein said second end assembly comprises a second end plate and a plurality of non-intersecting second compression bars, each of said plurality of second compression bars extending across a central region of said second end plate, said central region corresponding to the central, catalytically active region of said anode layer and said cathode layer, and wherein said compressive fastening means comprises a tie rod having first and second ends, said first end extending through an opening formed in one of said plurality of first compression bars and said second end extending through an opening in one of said plurality of second compression bars, a

first fastener for retaining said first end against said one of said plurality of first compression bars and a second fastener for retaining said second end against said one of said plurality of second compression bars.

22. The electrochemical fuel cell stack of claim 21 wherein each of said plurality of first and second compression bars consists of a pair compression bars.

FIG. 1

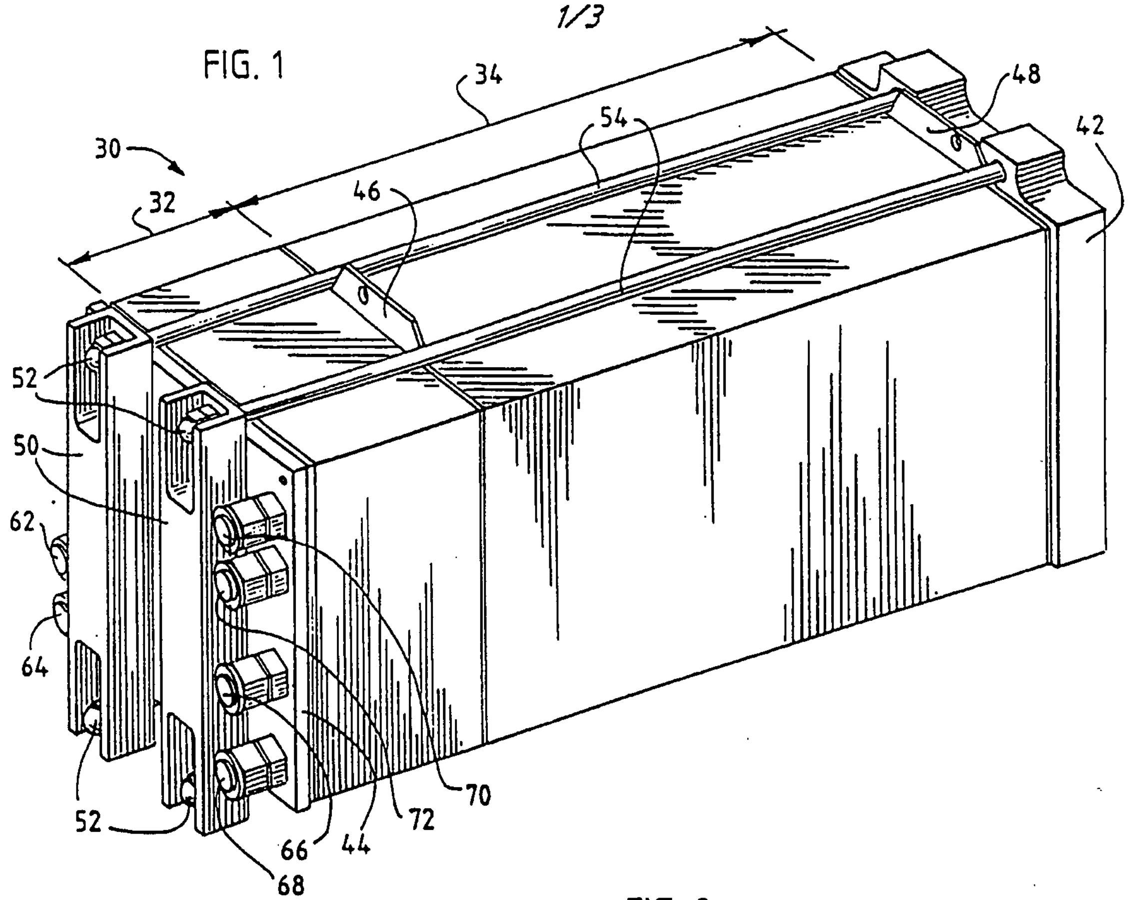
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FIG. 2

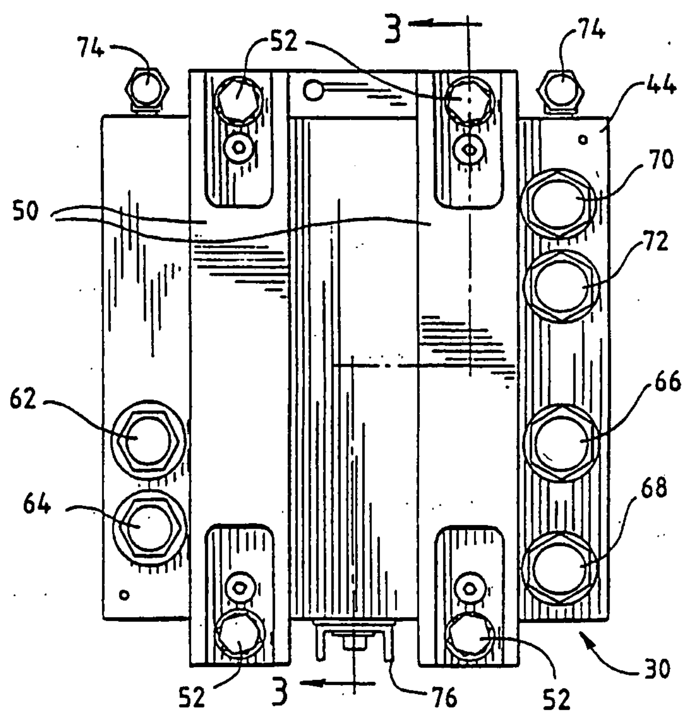
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FIG. 3

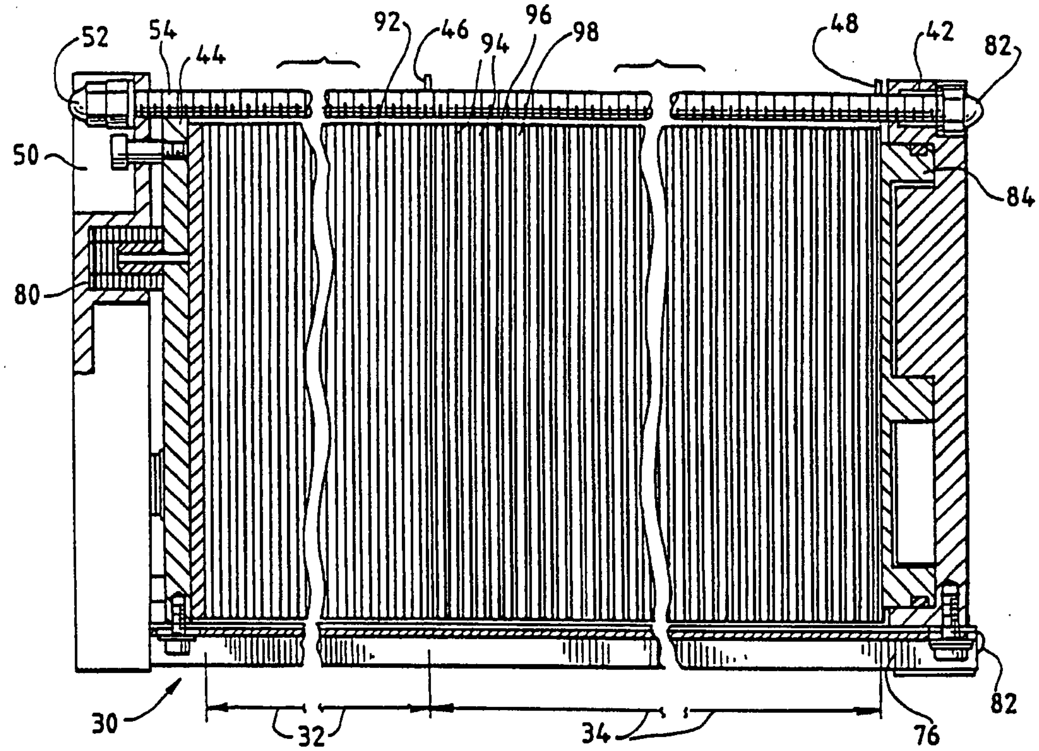


FIG. 4

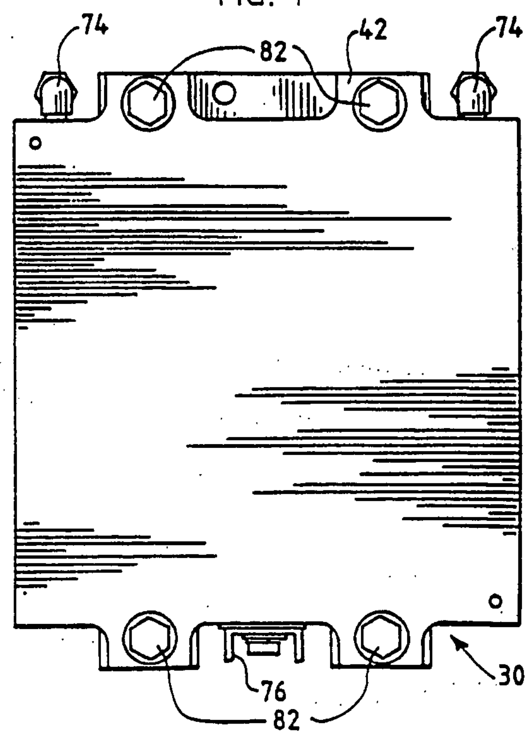


FIG. 5

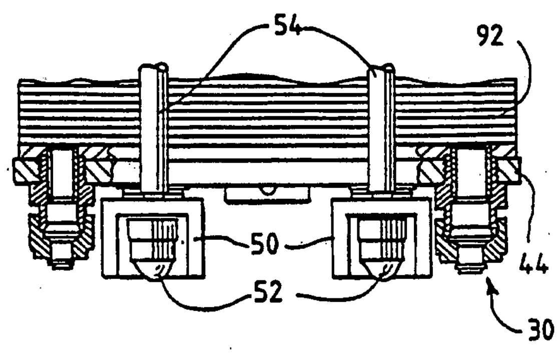


FIG. 7

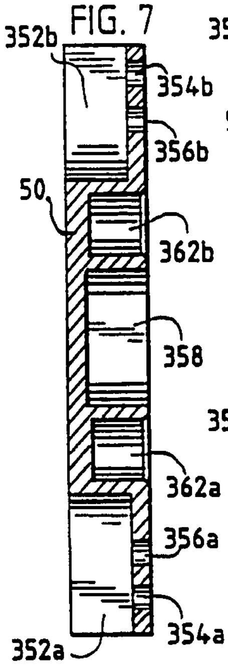
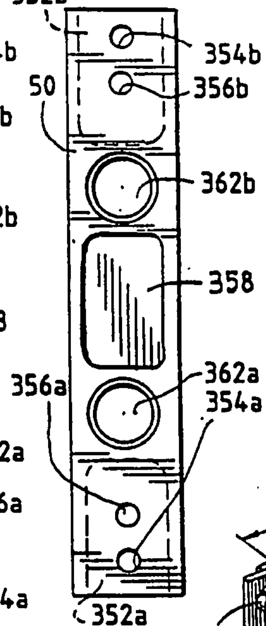


FIG. 6



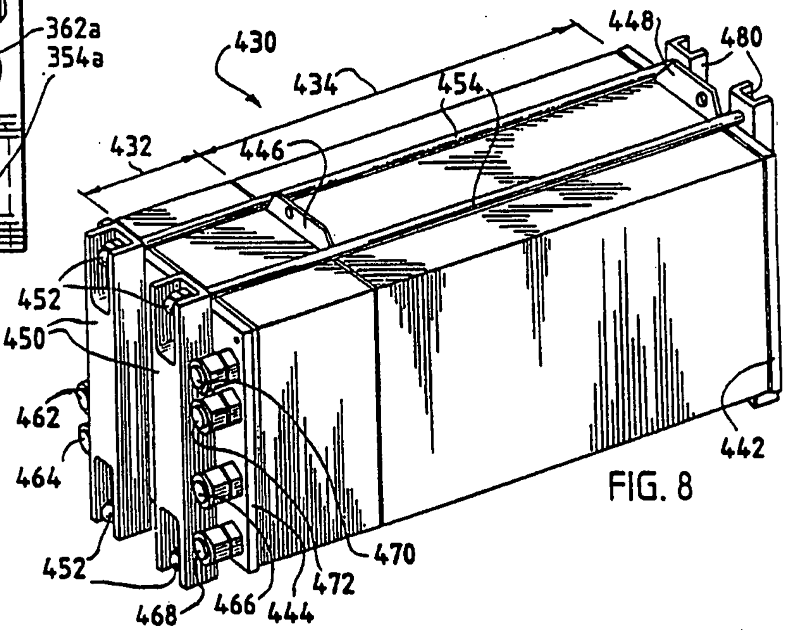


FIG. 8

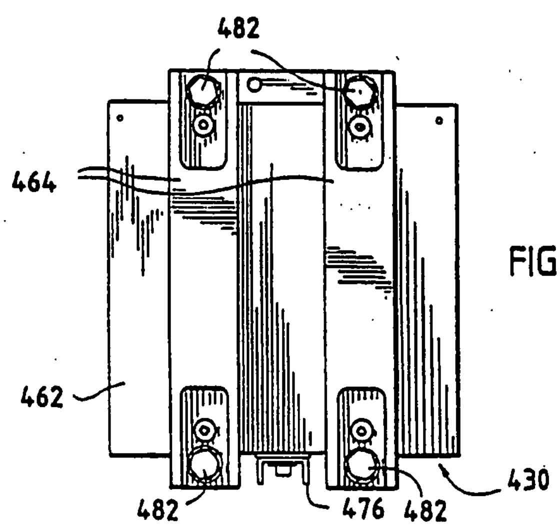


FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 95/00182

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US-A-4 692 391 (HIROTA TOSHIO) 8 September 1987 see column 4, line 8 - line 44; figure 6 ---	1,8,9, 12,19,20
A	US,A,4 615 107 (KUMETA MASAO ET AL) 7 October 1986 see column 3, line 39 - column 4, line 2; figure 4 ---	1
A	EP-A-0 575 178 (HONDA MOTOR CO LTD) 22 December 1993 see column 1, line 29 - line 37; figure 1 ---	
A	US-A-3 573 104 (SNYDER CHARLES W JR ET AL) 30 March 1971 see column 6, line 29 - line 51; figures 1,10,12 -----	1,2

INTERNATIONAL SEARCH REPORT

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